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FELICE FONTANA
SOMMO NATURALISTA
POMAROLO 1730-1805

Phytopathological Classics

NUMBER 2

OBSERVATIONS ON THE RUST OF GRAIN

BY

FELICE FONTANA

1767

A Translation by

PASCAL POMPEY PIRONE

Fontana, F. Osservazioni sopra la ruggine del grano. In Lucca 1767. Nella stamperia Jacobo Giusti. Con Lic. dé Sup.

With a biographical sketch and translator's preface by

PASCAL POMPEY PIRONE

Cornell University, Ithaca, N. Y.

Published for THE AMERICAN PHYTOPATHOLOGICAL SOCIETY
by the Hayworth Printing Company, Washington, D. C.
1932

ACKNOWLEDGMENTS

THE AMERICAN PHYTOPATHOLOGICAL SOCIETY thanks the translator, Pascal Pompey Pirone, Graduate Student in the Department of Plant Pathology, Cornell University, for his excellent rendering in English of this classical work of the famous Italian scientist, Felice Fontana.

The Society also gratefully acknowledges its indebtedness to Mr. Domenico Pirone, father of the translator, through whose generosity the publication of this translation has been made possible.

Thanks are due Professor Casimiro Adami of Verona, Italy, for the excellent photograph of the bust of Fontana, which appears as the frontispiece of this classic.

The translator desires to express his deep appreciation to Professor Lawrence Pumpelly of the Department of Romance Languages at Cornell University for his invaluable assistance in the attempt to attain an exact rendering of many difficult passages and a form of expression approaching in some degree that of Eighteenth Century English.

To Dr. H. B. Humphrey, Editor in Chief of Phytopathology, and to Professor H. H. Whetzel, thanks are due for their encouragement and for their assistance in reading and editing the manuscript.

FELICE FONTANA

Felice Fontana, famous Italian physicist and naturalist of the late 18th century, was born in Pomarolo, northern Italy, on April 15, 1730. He began his studies at Rovereto and continued them at Verona, Parma, and at the Universities of Padua and Bologna. He then went to Rome and Florence.

Fontana was chosen Professor of Philosophy at the University of Pisa by Francis I, Grand Duke of Tuscany. He held this chair until Archduke Leopold called him to Florence to build the museum of physics and natural history, which, even today, is one of the principal ornaments of that city. He invented many physical and astronomical instruments and also prepared with colored wax a form of the human body with all its component parts.

All of his time, however, was not spent in mechanics. He published many dissertations on physics, chemistry, and physiology. He wrote various articles in both Italian and French on blood globules, on the circulation of sap in plants, on the "tremelle" of Adanson, a species of zoophyta, on snake poisons, and also a few articles on plant diseases.

Very little is known of his private life aside from the fact that he frequently attended scientific-society meetings. He was loved by all who came in contact with him. Fontana died on March 9, 1805, after a great deal of suffering from injuries received in a fall.

Du Bois-Reymond once said, "Felice Fontana spread the light of science to all of Europe."

P. P. Pirone.

TRANSLATOR'S PREFACE

The following translation of Fontana's book was undertaken as a part of the course in the History of Phytopathology given by Professor H. H. Whetzel to graduate students at Cornell University. A copy of the original book was obtained from the Library of the United States Department of Agriculture at Washington, D. C.

Fontana's observations are very remarkable when one considers the period in which they were made. Were it not for the date placed at the front of the book, which removes all doubt, one might be rather sceptical that he was able to discover and so exactly trace the fungous nature of the rust many years before Persoon and DeCandolle mentioned it in their works. Although Fontana did not understand the relationship existing between the two forms of rust he described, there is little doubt, after one examines his fine plate at the end of the book, that he worked with *Puccinia graminis* Pers.

We have presented here what is believed to be one of the earliest contributions to the true causal nature of the stem rust of wheat. These observations were made in the course of a year.

Fontana's name is not to be forgotten in the science of plant pathology, for he stands forth as one of those geniuses whose misfortune it was to have lived long before the world was able to understand them.

P. P. Pirone.

To the Most Illustrious Baron Van-Swieten, Commander of the Order of Santo Stefano, Court Medical Councilor of Their Imperial Majesties and Perpetual President of the Vienna Medical Faculty, etc.

It seems fitting that a small book dealing with new observations concerning a little-understood disease of a plant, to the preservation of which ancients consecrated a Goddess, should be dedicated to no one other than that incomparable man who has enriched Medical Science by new, important discoveries and observations of the nicest type and recently through his profound practical and theoretical knowledge, has made the most fortunate application of it to the cure and conservation of a precious Life,[1] on which depend the destinies of Europe and which is of great interest to Humanity. You understand then, most worthy Sir, that this little book of mine could not be dedicated to anyone but you. I hope you will not disapprove of the respectful liberty with which I discuss in this work the opinions hazarded by many eminent writers on this subject, since, in more than one instance in your distinguished works, summoning for examination the hypotheses of the most celebrated masters of the art of healing, you confess the necessity of warning the reader, with proper liberty and wise council, against the influence of the celebrity. Therefore, the not unimportant discoveries, which I appear to have made on the most fearful and harmful disease of grain, should merit your approbation. I should be more than certain, then, of having merited the approval of all great men whose judgment cannot disagree with yours, just as their worth cannot disagree with yours.

FELICE FONTANA.

[1] Translator's note: Van-Swieten was made a Baron for saving the life of the Empress of Austria, Maria Theresa.

To him who may wish to read.

On the 10th of June of last year, I discovered that the rust, which had devastated the lands of Tuscany, is a grove of plant parasites that nourish themselves at the expense of the grain; and at that time I pointed this out to many of my friends here in Florence, and a few days later I wrote about it to the most learned men in Italy and other parts of the world. About this time a celebrated professor at Pisa, to whom I had mentioned it in a letter, honored me by writing a short article on it in the Venetian Gazette of Natural History. Be this said in all truth lest some believe that I may have profited from the pamphlet which appeared in Florence three months later. Therefore, I present my observations in this form to the public now. I present them to you, courteous reader, assembled in a small book because I know it is of little importance to you to know all that has been written or imagined on this question up to this time, and which I could have placed together and collected in a large book at little expense and work. Since it is beginning to be recognized that one may know the history of the thought of all men without knowing how to think, it appears that even the secondary and common class of initiates in Philosophy is being cured of the mania of quotations from both Greek and Latin texts, especially when they treat of works registering the facts of nature rather than the concepts of men. I certainly could have filled up a hundred pages alone with the citations of ancient authors, naturalists, philosophers, and poets on this subject and another 400 pages on the thought and suggestions of modern workers, and by covering it over with a mass of Greek and Latin and if need be with Punic and Palmyran, I could produce without effort and by mere copying an enormous and deadly volume.

But I willingly renounce all this glory and shall leave to others the courage of imposing so severely on your sufferance. I know that there are those who wish to see even a physical truth expressed in verse; and I once heard a famous dialectician seriously affirm that all the queries of natural history can be answered with the verses from the Georgics of Virgil. And are there not those who find the answers to all questions in Homer, even in our day? But enough of this.

I respect too much the Century of Philosophy and of Reason to wish to do it the injustice of believing it prejudiced in favor of the pedants.

"It is by well reasoned and prolonged experiments that one forces nature to disclose her secrets; no other methods have ever been successful, and true scientists must regard older systems as ancient dreams and must read the majority of modern treatises as one reads romances. The collections of experiments and observations are in truth the only books that can add to our knowledge.

"Let us always, therefore, amass experiments and turn away, if it be possible, from any idea of system, at least until we have some knowledge. We shall surely find some day a place for these materials, and, even if we were not fortunate enough to build a complete edifice, they shall certainly help us to build a foundation and perhaps to advance it, even beyond our hopes."

M. Buffon Préf. de la Stat. des Végét. de M. Hales.

PERSUADED by reason and taught by experience that the study of the errors of men is an idle and sterile occupation, if not a real loss of time for the Philosopher who seeks to discover the truth, and that hypotheses may for a time stir up the imagination of a poet but can not satisfy the intellect of a thinking man, therefore, since I wish to discuss the rust of grain and relate to the public what I have examined, seen, and observed on this point of natural history concerning which many and various things have been written to the great scandal of the sceptics, I have determined to point out only the principal hypotheses that are to be found on this subject in the works of naturalists, at the same time indicating and discovering their incoherence and falsity and then immediately setting forth that which I have decided and established, that which appears to me correct after having conducted many observations and long severe examinations. These observations were made by me last year, when a sudden severe attack of rust ruined the grain all over Italy and especially in the province of Tuscany.

From the beginning and even now many philosophers believe that the dust, which composes the rust, is a mass of very tiny animal eggs that are deposited on the leaves and stalks of the grain plant by a certain species of small worms or insects. It is also claimed that there were seen (and what things are not seen by the prejudiced mind?) emerging from those eggs, large families of living creatures which are fatal to vegetables and deadly to grain. Such an hypothesis could truly appear to be confirmed by some observations made by the industrious Ginanni, who assures us that he has often found very small bugs in the granulose powder of the rust. But such an opinion cannot convince an observer who has an unprejudiced mind, since the worms mentioned are found very rarely and are observed (when they are found) subsequent to the dews. They are found to be innocent and absolved of any harmful influence concerning the rust and are present there because of the shelter afforded them. The following observations, which I repeated many times, always with the same result, will break down an already weakened hypothesis.

The granules of rust were pressed tightly between two plates of glass so that the supposed eggs were broken; with a very powerful microscope I observed them being crushed one after the other. I can certify that no liquid or gelatinous humor came out of any of these, as no doubt would be the case were they animal eggs; that great force was necessary to crush them and that they were homogeneous throughout, being filled with a solid and resistant substance. The structure, then, of the powder that forms the blackish rust spots, as we shall see, resembles anything but an animal egg and is attached in such manner to the stalk and leaves of the grain plant that it does not agree with any proper or scientific character of ovules left there and deposited by whatever species of insect.

Other philosophers have advanced the theory that these minute bodies of the rust powder are, on the contrary, probably real live animals, being deceived perhaps by the tailed shape shown by the granules when observed under the microscope. A certain movement observed when they are examined in water contributed further to deceive some of the observers I have known. In the natural state the small granules composing the rust powder are sticky and slightly viscous and therefore remain united and piled together. When these are placed in water, the movement of water from grain to grain divides and separates them and induces such a motion among them that one who examines them hastily or who is not accustomed to seeing the spontaneous motion in the Infusoria can easily be deceived. A movement of such a nature between the granules is purely mechanical and is the ordinary effect of the water. This movement eventually slows down and is stopped, instead of increasing as in the case of aquatic animals; it is never observed in the rust that is still fresh and wet on the plant.

There are some who believe that the rusty powder of the grain is the work of very small microscopic animals, which alight on the plant during certain favorable atmospheric conditions. But this hypothesis also is contrary to experience, since these insects are rarely found or when they are found, as happens sometimes after a dew, no rust is present on the plants. Moreover, the complicated structure and great regu-

larity of the black rust make such an opinion improbable, and, above all, the attachments of those granular powders, show them to be anything but the work of insects.

Another theory concerning rust must be examined, which, sustained and reinforced by the authority of the greatest Italian philosopher, a man of great discoveries, and few mistakes, led many thinkers into error. The theory is that many diseases of grain, such as blight, smut, and rust are caused by solar rays, which, united and brought to a sharp focus by the drops of water, on the tender small plants, burn, scorch, and consume the grain and the leaves. He believed that the droplets of humor exuded from the plant or deposited from the atmosphere, act as burning lenses, which unite the parallel rays of the sun and condense them into a small point on, or a little below, the epidermis of the plants, where they scorch and blacken the integuments. This ingenious hypothesis also is subject to the fate of all the others, namely, that it is not in accord with the facts. There are certain facts that show that neither mildew nor smut originates from those drops of water that are transformed into burning glasses; and, in our case, it is certain that rust appears only when the sudden cold of the night is not properly proportioned to the heat of the day and when dry heavy fogs appear, at which time the dreaded drops do not exist. Another current idea is that the diseases of grain appear after the dews and rains, but precisely the opposite occurs; moreover, all the other species of plants should be visibly scorched or burned since the above-mentioned drops are found on all plants. It is certain and beyond doubt that the very minute drops of humor could never collect such an abundance of rays as to blacken and char the most delicate and fragile part of the tenderest plant. It is absolutely necessary that the lens have a considerable diameter and that it collect a sufficient quantity of rays which when united in a common focus have the strength and activity to burn. This diameter of the lens must be incomparably greater than that of the very minute drops covering the plants. Out of my own curiosity, I have many times sprayed water on the most tender living plants and have done the same on the leaves and stalks of already dried and completely withered plants; I have then exposed them for a very long time to the

very hottest rays of the sun at midday and have never noticed any burning or blackening in any part. I have many times placed tiny lenses and beads of fused glass on various leaves and I can assure you with certainty and without fear of error that the light, collected and condensed in their foci, was entirely harmless and inactive.

Finally, the most common and accepted theory, even among modern observers, is that the powder of the rust is only a humor or an exudation of the plant that arrests itself and degenerates into granular powder during certain periods and under certain circumstances; or, as others believe, it is a large and viscous humor left there by the air at certain times; or rather, as the celebrated Tillet claims, it is a sour and deadly humor dispersed and radiated by the air during cloudy periods, which corrodes the tender fibers of the leaf and stalk, causing a diffusion of the fatty and oily juices, which, upon drying, are converted into a reddish orange powder; or, finally, as Hales claims, it is the nutritive juice of the filled plant that becomes stagnant and sours in the vessels, which, in turn, infects and spots the plant. A single observation made on the structure of the powder is sufficient to prove all these hypotheses false. If that powder were a humor left by or gathered on the grain plant, it would be formed of globules and would never appear to be made partly like an egg and partly with the shape of a real plant with a cup, stem, and acorn, as we shall see later on. An uncontrolled and irregular fermentation, a humor that drys and hardens, would never be capable of forming bodies so regular, and so constantly regular, as are those composing the rust. The attachments that are constantly observed on the black and red rust and the mutual supports of those small bodies could never result from those causes that have been imagined by the naturalists who did not consult nature. *"Quam bellum est velle confiteri potius nescire quod nescias, etc."* (What a fine thing it is to be willing to admit you do not know a thing that you actually do not know, etc.)

But already, I feel weary of being in the land of dreams and realize that I am impolite in detaining the reader longer

than is fitting in discussing them. Because of the disagreement and uncertainty among the most modern philosophers, I believed that the solution of the problem could be found only through correct observation and a more exact and diligent examination of the powder of the rust. I collected a good quantity of the said powder, which I took from a great many grain plants, sometimes by shaking and sometimes by removing with a penknife where the plants seemed most spotted and discolored. When placed on a piece of glass and examined with powerful lenses, I observed them to be piled in various groups; I was unsuccessful in separating them with a needle point, since they appeared to be covered by a thickened humor that kept them together. This powder was composed of two kinds of minute bodies; some were ovoid, and practically of the same form and size; others were very long and, in some respects, similar to minute fungi or to ordinary nails.

The bodies of the first kind, that is, the ovules, generally appeared opaque or very slightly transparent, even in the strongest and most active rays of the sun. They were ovoid for the most part; some resembled ellipses, and a few others were slightly pointed and irregular at one extremity. Their color was a rather dark reddish yellow, with dark extremities. Many of the bodies were transparent at the two extremities or points; others had thin translucent rings around them with an opaque reddish yellow ovule in the center. This more highly colored oval spot is seen in the center of the eggs that have the transparent rings around them, having the appearance of an opaque egg at the center of an elliptical roll.[2] Some of these ovules are spotted with dark points above the colored part but never above the transparent part. I have found a few that were translucent, colorless, but these are so very rare that less than one in a million is found. When they are piled upon each other they become much darkened and almost black in appearance; when separate and divided they are yellowish red or the color of yellow and opaque glass.

[2] Translator's note: Roll, i. e., cake or biscuit.

The other kind of rust powder had the appearance of fungi in groups, or mounds of nails with large rounded heads. These tips or heads were attached to a large long cone, giving the appearance of acorns set in cups, which, in turn, were attached to very long stems. These nails were so bunched and tightly united together that a jarring of the glass slide on which they were placed could not separate them, and the point of a needle was capable of separating the bunches only enough to form smaller ones. Here and there, however, were seen a few that were totally isolated or in contact with only two or three others. The same was observed in the other kind of rust, which is composed of small eggs; some may always be seen that are isolated from the rest or attached to a few others, depending on the amount of moisture in the powder, the manner in which it is removed by the needle point or knife, and, finally, on the method of preparation for microscopic examination. The nails appeared darker, and blacker where they were massed, and transparent when there were few. When few are together or when they are observed singly, their color is yellowish red; perhaps somewhat darker than that of the little eggs, especially the head of the nail which appears black and opaque when it is united to several others and is observed in reflected light; the cup in this case is also very obscure and nearly black, but when it is seen isolated it has the usual yellow red color. The stem of these cups is always transparent and translucent, especially in the center and towards the tip, at which places it appears to be made like a crystal or ice.

If we divide these bodies of the nail-like rust into three parts, namely, the head or acorn, the cup or cone, and the stem or root, we see first that the heads are not so uniform as the eggs either in size or in form and shape. Some are round, being perfect spheres or little balls; others are very long and almost cone or pear-shaped, since they taper to an acute point; these made up the largest part of the types found; others are somewhat irregularly ovoid with apices that have a bulge or protuberance at times and that end in a blunt point; and others are long and olive-shaped, though very few of the latter are ever observed. I have found a few (but

these are very rare and are found only by chance after a thousand fruitless attempts) with a peculiar form and structure, which have a long thin horn or spine that ends in a very acute point, projecting at the center of and lateral to the head. The heads or acorns appear to be set into a cup or cavity which hides a part of them from the eye of the observer.

The cup is a long conical body, more frequently straight than curved, and at times somewhat irregular; in some nails it is bulged, while, in others it is thin and slender. A darker ring or small circle appears at the uppermost part of base of the cup, inside of which there appears to be a cavity into which the head or acorn partly sits, as has been mentioned. Sometimes the ring is larger or wider than the acorn that it holds, but more often it is much smaller. In some, the ring appears to stretch outside of the acorn; in others it is very small and appears as a thin slender collar that supports a large head. Some cups are very long and widen out towards the tip because of a large bulge found towards the middle; also others are very short and decrease in size from the base to the tip. Once I chanced to observe a cup without its acorn, which happened to be in close proximity to a little egg, and I could see very well that they did not belong to the same plant. It is, moreover, true that it is extremely rare that one can make such an observation but in such a case one can observe a rather shallow cavity the form of which corresponds to the base of the acorn that had rested in it. All the stems usually end in a somewhat obtuse or blunt point. It is true that a large number are found broken off near the tip, probably when they are detached from the grain plant. At times the stems are conical, very slender, widening towards the tip and transparent throughout their length, which equals the length of the cups, which in turn are usually longer than the acorns.

When a droplet of water is placed on a mass of those fasciated nails, they begin to move in various directions, and they separate into smaller bundles as the water creeps in between them and neutralizes the effect of their natural glutens. These are all united together as much as possible, since very

few are observed alone; and, even when one tries to separate them with a needle point, very few totally isolated bodies are found. The movement lasts for a few minutes, until the water has fully permeated them; the motion is derived entirely from the water that permeates them and, as I observed a thousand times, it is certain that the bodies that have already been separated are motionless; nor does it appear that they visibly imbibe water and increase in size, even though kept in water for a long time. During the time that such a movement lasts, the tailed bodies, which resemble the spermatozoa in some respects, can easily be mistaken for minute living eels; and, in fact, I have known more than one person, whom I have put to test, who believed such a thing. But such motion is certainly mechanical, and is produced by water, since no spontaneous movement or tendencies or directions can be found as may be observed in the case of all microscopic eel-like animals; and the motion does not continue but ceases after a short while, even though they are still in the water. The same may be said of the eggs, which also move when they are placed in water, although their movement is less active and of shorter duration because of their shape and minuteness.

The observations made up to this point lead one immediately to suspect that the nails are very minute plants that nourish themselves at the expense of the grain. But, after all, this is only a suspicion and an hypothesis. It is true that some light could be shed by chemical analyses of the rust powder, by determining whether an acid or alkaline humor is given off, and whether it is vitrified or calcined by fire. In fact, Ginanni has subjected the dust to fire and assures us he had extracted a strongly acid fluid. But these experiments are always somewhat dubious and apt to lead into erroneous conclusions anyone who cannot modestly suspend his own judgment and make up his mind to appear as second in importance. For example, it is known that vegetable substances like the galls, form ink when they are united with vitriol. In order to determine whether certain vegetable excrescences that are found on trees were vegetable or animal matter, Count Marsily united them with vitriol and succeeded in obtaining ink; he hastily and without proper circumspection con-

cluded that those tumors were real galls of vegetable origin. Lemery succeeded in making ink from animal excrement and finally from human excrement, showing that vegetable matter retains its ink-making properties after it is passed through an animal body where it is broken down and digested. The great French observer, M. Réaumur, succeeded in converting Marsily's galls into real insect galls.

A vegetable substance can in a thousand cases retain either many or few of its original properties, even though it seems to have changed into an opposite substance and to have acquired new and different properties. Some workers have been able to extract a slightly sour liquor from putrefied meat, and the celebrated chemist, Vallerio, has even succeeded in vitrifying (crystallizing?) animal substances, as, for example, the solid part of ox blood. These experiments contradict general conclusions which are hastily deduced and elevated to the dignity of axioms.

But, even though those experiments prove that the rust is a vegetable substance, there would still be much obscurity and uncertainty, since we would not know whether those plants are foreign to grain, whether they are a humor of the stalk or the leaves which is collected or fixed, or whether they are a dewy substance or some other humor that is deposited by the air under certain conditions, and then solidifies and enlarges by evaporating the most delicate and volatile parts.

I had all these ideas fixed in mind and the figure of the small plants found in the rust was always impressed on my thought; I suspected that they really were parasitic plants that were carried by the wind and lodged in a suitable and adapted place to feed at the expense of the grain. It is true that those bodies terminated in a simple, unbranched root, unlike other plants, which are branched; however, at the present time we know that there are plants that do not have roots, as in the case of the truffles, the *"Care-folium of Paracelcus,"* i. e., the *"Flos coeli,"* or the *Nostoc,* which dries up as soon as water is deficient and is barely visible, even though a little water be sufficient to enlarge it and renew its life and vigor.

We also know that there are other plants that terminate in a simple point and are unbranched. *Lenticula* and *Lenticularia* of Micheli do not have branched roots but end in a slender thread that appears to enlarge as one proceeds from the leaf and whose point enters into a larger conical sheath. It is true that these are aquatic plants; but I do not see why the rust cannot be considered in the same light, as a plant that lives on the juice of grain surrounding it, just as *Lenticularia* lives in the surrounding water. Micheli, in his work Nova Genera Plantarum, page 128, describes, among the plants, *Suillus,* a very large mushroom, which the Italians call the Malignant Porcine Bodkin, whose roots terminate in a point. Several other smaller ones are figured in table 80 by Micheli; on page 204 he describes the fungoid types, some of which resemble in some respects, the long bodies of the rust. Some very small plants resembling the rust may be found among the *Clatroidi* in table 94. On page 84 the same author describes some small lichens that have, in addition to the cup, also at the tip a head or cap, in which respect they closely resemble the rust. Although these plants have something in common with the fungi, lichens, etc., they are very different in the remaining parts; and, though we do not have sufficient evidence to suppose them real plants, we have even less evidence to suppose them fungi or lichens. They might possibly be related to the molds described by Micheli, but those plants are far more tender than the rust and do not have the uniform structure similar to that of the rust. Then, too, we find seeds or buds in all the plants such as the lichens, fungi, and molds; I am still uncertain whether seeds are present in the black rust; however, it has not yet been shown whether the "Byssi"[3] have real, at least visible seed, and, besides, it is very certain that they are not found in many other plants.

In the final analysis, even though all these facts further the opinion that the rust is a mass of parasitic plants, they do not positively prove this point. It was necessary to examine more closely, combine, compare, analyze and compel Nature to reveal her secret and catch her in the act. In the course

[3] Translator's note: Probably white mycelial masses.

of my experiments I have observed many times a singular and little-understood phenomenon. I observed with the microscope that the dust, which I gathered from the stalk or leaf with a knife, was made up at times only of small eggs and at other times of piled nails without a single egg attached to them. Such an occurrence made me suspect that there probably were two kinds of rust or at least two different forms of the same. With this suspicion in mind I examined the rust on the stalk more closely and discovered two kinds of spots, which were very different in appearance, some having a very black color, while others were yellowish red or cinnamon. I then examined the dust from the black-rust spots and found to my surprise that it consisted only of nails or plants, among which I could not find a single egg. I repeated this observation, always with the same result, at least a thousand times; that powder always consisted of the bundled and heaped plants and never of eggs. On the other hand, I always found that the powder obtained from the reddish spots contained only eggs and never the ordinary plants of the black rust shown in figures 1 and 4.

The grain plants that I examined, then, were attacked by two kinds of rust; one that appeared perfectly black to the eye, and the other, the color of rusty iron or a reddish yellow. The former was composed of nails or long bodies with stems, while the latter consisted of eggs. They both were practically the same reddish yellow when examined with a powerful lens; and, if there was a little difference, it was found in the heads of the nails which appeared darker, that is, more laden with the reddish yellow color; but they never appeared black, like the powder from which they were taken.

After the fact had been established that two species of rust attacked the grain, and that the black rust contained bodies with long stems, resembling small worms, one observation remained to be made, which alone could determine with the most excellent physical evidence whether those bodies really were plants. It was necessary to determine whether they were fixed in the stalk or leaves, as plants are in the earth, i. e., to determine whether they were growing perpendicularly with their stems attached inside and the heads or caps outside, as

is the case with lichens, fungi, and even with molds. This observation, combined with all the preceding ones, would leave no doubt and would compel the less measured and less temperate sceptics either to believe them real, living plants or to exclude impolitely from this rank the lichens, fungi, and molds, thus doing the botanists the wrong of degrading from the order of living organic bodies those which they themselves have elevated to it with legitimate and non-usurped authority. After cutting with a knife several times into that part of the stalk which was spotted with black rust, I observed with a microscope the cut fibers and the dust adhering to them. One day I observed ten of the described bodies attached to a round small fiber. They were attached by their stems to the fiber or strip and their heads projected out, as is shown in figure 2.

Although this observation was of much weight in determining the nature of the above-mentioned bodies, it was not final because the fibers to which those bodies were attached by the stems were very rarely seen and it was difficult to determine exactly when they were observed on the glass, whether those plants were growing perpendicularly on the stalks. To solve this problem I thought of examining the spots of rust on the stalk itself without laying them on the glass. First of all, I wanted to compare the spots as they appeared to the naked eye and under the microscope. The black and the yellowish red spots as well, were spread in long streaks parallel to the leaf and stalk fibers, and were never placed in a transverse or opposite direction to the fibers or vessels of the plant. These longitudinal spots, which, because of their minuteness, sometimes appeared as dots, were rough to the touch and seemed somewhat raised on the stalk or leaf, even without the aid of the microscope. The stalk and leaves appeared to be penetrated with large or small furrows, depending on the size of the spot when the powder especially of the black rust, was removed either by shaking or beating the plant or especially by soaking it in water for some time. The powder was viscous and sticky and stained when rubbed between the fingers or linen cloth, where it easily stuck.

The epidermis was broken where the small cavities or fur-

rows of the leaves and stem contained the black or reddish yellow powders, and it was raised above the spot in many places, giving a "torn-dress" appearance to the furrow and the powder it contains. This irregular epidermis does not cover the rust fissure entirely, but only in part and this around the circumference, while there is a broken and torn appearance in the center; the epidermis usually exposes the black rust more than it does the red.

After thus examining with the naked eye the two kinds of rust, as it appeared on the plant, I examined it with great care under the microscope and in the same position. When examined with two lenses of a Cuff microscope, the black-rust spots had a saddle-shaped appearance and seemed to consist of a black globular material, for the black spots were raised in the center, forming a ridge or curved hump. Where the spot was blackest and largest, it was either entirely free of epidermis, or, if there was any membrane at all, it was torn and small in extent and left the greatest part of the black spot uncovered. The epidermis covered the smaller and lighter spots, arranged in narrow stripes, in many cases covering them so well that the small granules of black rust could be seen only through some small longitudinal fissures that sometimes were extremely difficult to find, even after very diligent perseverance. I have never been able to find a single pustule of rust above the epidermis. I must not deny that at times, though very rarely, I was unsuccessful in observing an opening in the epidermis although on looking through it I perceived underneath the usual heaps of black powder that I took out with a lancet, in order to be more certain. In all instances where the epidermis was seen covering the powder, either completely or in part, it was always raised notably, forming a tumor or swelling, depending on the amount of powder under it. It is not difficult for an observer with a microscope to believe that the unruptured epidermis, which covers the black rust, had real plants under it, nor could he believe that the rust is a humor given off by the canals of the stalk or leaves of the grain plant merely because he does not understand the means of their entrance into the plant. This is the point on which the great mind of the Tus-

can observer, Francesco Redo, failed. He observed that animals lived under certain vegetable excrescences and since he could never find an opening through which they entered, he concluded that the plants had the power of producing live animals, but, today, everyone knows that the humor that diffuses from an injured plant can easily and perfectly close a wound.

I finally observed a great number of spheroid bodies that touched and were piled one upon another, after examining with very strong lenses, those masses or mounds of black globular powder on many stalks and leaves of the grain plant. On carefully turning over a piece of stalk on which they were attached in great quantity, I perceived that all the spheroidal balls had a long stem with the point of which they were strongly attached or fixed on the stalk.

With the aid of a powerful lens they looked like a crowded grove of trees planted at equal distance on the above-mentioned furrows. The heads were raised and, like the stems, were closely pressed against each other. They touched each other in such manner that the plants on the edges, farthest from the center of the crowded grove appeared slightly oblique and inclined, while those away from the edge and closer to the center were all erect on the grain stalk and planted perpendicularly, like other ordinary plants.

It is certain then that the black rust is made up of very small, regular and compacted parasitic plants. The celebrated Henry Backer discovered a microscopic plant in the sand of the Thames which very closely resembles our plant. This plant is larger, but, as can be seen from figure 8, is very similar to our vegetable nail in form and color. Like our plant, it is composed of a ball or head, a cup, or paunch, and a stem or root that is planted in the sand. The head is round, and is set in a swollen collar or cup, that ends in a broad paunch that is connected to a very short transparent stem. The head or ball is dark and the paunch is a reddish yellow or chestnut color. Backer thinks the little ball is the fruit or the seed of the plant.[4] However, as we shall see later, the little ball does not seem to me to be the seed of the plant.

[4] Translator's note: Apparently a species of Pilobolus.

Perhaps one might also consider the eggs of the red rust as just so many real ovoid plants, since, after all, each disease is a real rust of the same plant. But merely their simple egg or ball shape certainly is not sufficient proof that they are plants; besides, I do not know whether plants of such a character have been observed in nature. The works of many writers, even during the century of the Real Philosophy, are, alas, often full of dreams and impossible hypotheses because of the lack of correct observations. The scientific observer must convey to posterity only those facts proven by experiment, the sole teacher of every natural truth. The more philosophers examine substances, the more the argument of analogy proves itself to be fallacious, and for this reason, it will always seem suspicious to true observers of nature. It is certain that no one who has not observed the eggs of the red rust with a microscope could ever persuade a real observer to believe they were real plants because of the absence of suckers or absorbing papillae, of stem or foot with which to attach themselves, and because they are scattered at random on the leaves of grain even where there are no ruptured vessels or wounds from which they could obtain nourishment. All these reasons militate against the person who advances the opinion that the eggs are seeds, fruits, or other parts of the parasitic plant of the grain rust and who has no positive observations to prove it. What, then, are the eggs if they are not of vegetable substance? If experience is lacking they can be anything since their nature is unknown, but, when their nature is unknown, the philosopher is silent. It is necessary to have positive and illuminating proof to say that a body is of a certain nature and has certain properties; otherwise, the researches of men are nothing more than pure imagination and the probability that a body is what we imagine it to be, is very slight. The person who accidentally formulates a truth without observations must be called more fortunate than wise and he should never believe himself to be the true discoverer. The person who first demonstrates a natural truth is the author and not the man who states it; otherwise, Democrites, not Galileo, would be the discoverer of the satellites of Jupiter, and the learned Adanson is right in recognizing Jussieu as the only discoverer of the *Polypi,* even

though Imperati and Peyssonel, long before his time, judged them the work of insects.

I have not overlooked a single precaution in order to discover the nature of the eggs of the reddish yellow rust, since such an investigation is absolutely necessary for a full understanding of this pernicious disease of the grain. I must frankly confess that I did a great deal of work before proving to myself with certainty what the nature of those minute eggs is. The observation is most difficult and a thousand things combine to deceive the observer. Some of my friends who aided in the observations believed that the eggs were the caps or heads broken off from the cups of the plants of the black rust, being deceived by the apparent similarity of the heads to the little eggs. But such a resemblance can deceive only one who is satisfied by simple observation and one who does not consult nature with the proper diligence and is not very well acquainted with the use of the microscope. It is certain that the eggs are never found in those places where the groves of the parasitic plants are perfectly black and it would be like saying (for anyone who confuses the eggs with the heads of our plants) that citrons and not oranges belong on orange trees in spite of the fact that the citrons are never found where the orange trees are. Even on careful examination the parasitic plants of the black rust are never found with the eggs, when the latter are collected from the reddish yellow spots in which the color is equal and uniform throughout. If those bodies were really the heads of those plants, it is certain that parasitic plants without heads would surely be found among the infinite number of eggs. With the point of a needle I have removed a great number of those nail-like plants from the leaves of grain that had been allowed to soak in water for a long time and I have gathered a great quantity of red eggs without ever finding any cups without heads. It is true that among a great number of plants of the black rust I once observed one without a head near which an egg lay; but an observation of this kind is in the final analysis one of the rarest; and, then, too, the egg was not similar to the head of our vegetable nails but resembled more an egg of the red rust. This egg probably was on the slide on which

I previously had had red rust, although I thought the slide was cleaned thoroughly. It is also certain that the eggs of the red rust all resemble each other in shape and size, which is not the case with the heads of the nails. The bodies of the red rust are all ovoid, and there is very rarely any irregularity among them, while those of the black rust, as can be seen from figures 1 and 2, are very different from one another when observed closely. The bodies in the latter are ovoid, conical, spherical, and of other various figures and shapes. Such an observation is quite convincing but is not the only one that is so. I have tried a thousand times to remove the heads from the cup both with a cutting needle and by crushing the entire plants between two glass slides but always to no avail, since the few times that the head appeared separated, it was always ruptured; I also tried to separate them by soaking the plants for a long time in water, but I found that the cup and stem, instead of being detached, was broken up and torn, and the head was entirely crushed without becoming at all detached from the cup. It is true that eggs of the red rust have often been observed among plants of the black rust, and the plants of the latter among the eggs of the former; but this only proves that there are red spots in the midst of the black spots and black spots in the midst of the red ones, which are noticeable to the naked eye; such spots, being made up partly of black rust and partly of red rust, just as bodies of a different nature are found among the most crowded groves of higher plants. But what are these little eggs if they are not the heads of our nail-like plants? The following is what I have observed regarding the nature of the eggs, which for some time was quite unknown to me and which I almost despaired of ever discovering, and the more I observed this powder with the microscope, the less it seemed to me to be a real plant or a part of some plant. Such a regular rounded body appeared to me to belong to anything other than the vegetable kingdom and, even though it did belong there, one might perhaps feel that it was a humor that diffused out of the stalk or leaves of the grain and dried and hardened on them, or else some humor deposited there by the air, as so many philosophers had believed to be the case in the grain rust. But I was dissuaded more and more

from believing them to be organic plant bodies because I could never find stems or roots with which they could attach themselves to the plant, or papillae or suckers with which they could extract the juice, nor could I find any signs of rupture. There was added to all this the fact that many times I found the oval granules scattered here and there, where certainly neither scar nor rupture of the vessels was apparent, situated on the longitudinal axis of the plant. On examining the largest red spots more closely I found the bodies crowded and piled on one another. In some cases these were seen situated on very long transparent threads that were intertwined among each other in a thousand ways so that usually I was unable to perceive either beginning or end of them, as can be seen in figure 5.[5]

I had accidentally seen in the course of my observation of the red rust a few eggs here and there, attached to an appendage or stem; but I found only three of these among the many millions I examined, and these were so much more irregular and so very different from the stems found on the plants of the black rust that I believed them to be freaks or rather degenerates of the same plants. All this nevertheless made me more eager to observe the eggs. And, in fact, one day while examining a large quantity of the rust I had obtained from many very red spots on which there were no black rust plants, I discovered, with an excellent lens, a perfect egg with a beautiful stem or transparent appendage as may be seen in figure 4, z. This appendage increased in size toward its extremity, where it was attached to the egg. The perfect egg-shape and the very regular stem made me suspect that there was another parasitic plant different from our nails and that the eggs were the fruits or pericarps of this plant. I was all the more confirmed in this opinion because I thought I understood now why these eggs were found without stems or any sign of attachment. The very slender stem must easily be broken off at the slightest shock from its point of attachment to the eggs at which point it is very thin and fragile; hence I understood why the eggs were found without stems

[5] Translator's note: Fontana here probably mistook the vertical walls of the epidermal cells for threads of the fungus.

or visible signs of attachment and were found on the different parts of the leaves or stalk of the grain, carried by the wind to those places where there were no scars or humor to nourish them. These reflections made it seem even more probable that the red dust also was composed of plants; this, however, being only a suspicion which lacked more certain evidence to establish it as a fact. In order to prove that hypothesis, it was necessary to determine just how the eggs of the red rust were attached to the leaves and stalk of the grain plant. If these were heads of parasitic plants, like the caps of the plants in the black rust, and if the form shown in figure 4, z, is a real plant, we should find that the eggs in the red spots are standing erect and not lying down, since the stem is attached lengthwise to the egg in figure 4, z. Although such an observation is very difficult to make, since the dark spots of the red dust are very difficult to illuminate properly, I succeeded after many trials in assuring myself without fear of error that the eggs all stood erect and were closely pressed together. I used a very accurate lens, mounted between two fine silver wires fixed at the center of a very bright silver mirror. Thus assured that the position of the eggs found in the red rust spots was such as to verify the hypothesis that these were real plants, there was necessary only one more decisive observation, similar to that I succeeded in making in the case of the black rust. But try as I might, I was never able to determine how the stems, appendages, or roots of those eggs of the red rust were attached to the leaves or stalks of the grain plant. I examined the red spots in a million ways, with every kind of lens, at all angles either at perpendicular or at oblique angles, with strong and weak light, with reflected or refracted light, but all in vain. I was never able to see a single root in this manner. The eggs were so closely pressed together that it was impossible to see their stems by any means. Almost despairing of success, I finally devised a new method of observation. With the aid of a very sharp needle, I gathered the very fine threads or capillary fibrils from the spots of red rust that were on the stalks and leaves of the grain and tried to the best of my ability not to break off the granules that covered them. I examined these threads both on the glass and when suspended

in the air by a fine steel wire. The examination of most of these threads confirmed more and more my opinion that the eggs of the red rust were attached to very slender stems and were parasitic plants, completely different, however, from those of the black rust.

Finally, I observed one, shown in figure 6, which clearly showed that the eggs were the heads or fruits of very fine filaments attached to the stalk of the grain plant. The filaments of the eggs were very slender and transparent and they appeared to thicken at the extremity farthest from the egg. Assured by this observation, which showed that the eggs rested on filaments attached to the grain plant, I wanted to determine further whether or not they were plants growing perpendicularly to their resting position. I cut with a razor the portions of the leaves or stalk where the red rust appeared thickest and thinned them by removing as many strands of tissue as possible so as to make them transparent to the eye. I passed the point of a sharp cutting needle longitudinally through the spots until they appeared to the eye divided into very slender threads. This bunch of red threads was united at one end and was held in the air by a steel wire; in this way I could observe many threads at one time without further preparation. One of these threads, shown in figure 7, shows the characteristics that make it evident that, like the black rust, it is made up of plants. Growing out of the edges of the thread a very crowded grove of translucent filaments could be seen whose tips were attached to the red eggs. These fine threads were situated perpendicularly to the fiber of the grain plant, similar to the stems of the black-rust plants. In all the infinitely numerous examinations of the red filaments, I always observed that the eggs were attached to slender stems, which were always perpendicular to the thread itself. These stems are incomparably more slender than those of the black rust, and do not have the cup or body that holds the eggs; the threads are very fine and barely visible, even with the aid of the finest lens. In many cases entire thickets or groves of stems without heads were found, a situation never found in the black rust. I have noticed many times that the slightest movement made with the tip of a hair is capable of

breaking off immediately the egg from its stem. Now one can understand why we find eggs without stems in so many places on the grain plant, stems without eggs, and why we do not find the cups of the black rust without heads. The eggs have weak attachments, while the heads of the nails have strong ones, and are furthermore held firmly in their cups, which are of a hard, resistant, and corneous nature.

One can understand also the reason for the difference in color between the black and red rust. This is not due to the somewhat darker color of the heads of the vegetable nails but is due principally to the fact that light cannot pass between the nails because of the large size of their cups vertically disposed on the stalk, nor can light penetrate the heads and cups when they are observed longitudinally as it can when they are few, isolated, and observed transversely.

Assured of the real vegetable nature of the two parasitic plants of the two kinds of rust, the next problem to determine was whether or not these plants had flowers, fruits, seeds, or buds like perfect plants or whether they do not have those bodies, as many botanists claim is the case in the "byssi," many *Fucaceae,* and many species of fungi, which they, the botanists, call imperfect plants. In spite of all the efforts I have made, I must confess that I have been unable to determine whether the plants of the black rust have real flowers, seeds, or buds. It is true that these plants are so minute and become adults so rapidly, that it is very difficult to determine this point either because they are not easily visible even with a microscope or because I have not looked at them under glass at the proper stage of maturity. The latter reason is more significant than the former. I have examined those little plants a thousand times and have never observed anything that resembled or that I could imagine were flowers or real seeds.

Although the rust plants are very small, probably the smallest in the world, I am sure I would have seen the flowers under the microscope, had they been present, even though they were a thousand times smaller than the plants shown in fig-

ures 1 and 6. With all this I have not the intention to conclude anything or deny anything where more positive observations are lacking. Botanists never suspected the presence of stamens in imperfect plants until Micheli discovered them, even though, for the most part, he had himself taken the buds for male organs. The stamens of *Pilularia* and of *Lemma,* discovered by Jussieu for the first time, and in other ferns by Maratti; and many other minute plant parts, never even suspected, were discovered after the microscope came into use. The seeds of some algae, of mosses, fungi, and of ferns have been discovered in our times; and who knows whether a better-oculated observer might not still discover those belonging to the plants of the black rust. I wish to point out one observation that might lead us to suspect that those plants have seeds, which are enclosed in the heads or acorns. I have seen what appeared to be very minute ovoid bodies come out of the acorn or head many times on breaking or rupturing the plants with a sharp needle or between two glass slides.

There have been workers with whom I have come in contact in the course of my experiments who suspected that the eggs of the red rust and the heads of the black rust were the seeds of the two species of parasitic plants. Such an opinion does not appear in any way defensible. First, the large, in fact, enormous, size of those bodies in comparison to the plants, makes this hypothesis quite improbable. The eggs of the red rust are hundreds of times larger than their trunks or appendages, and the heads of the black rust are half as large as the cup and the stem together. Secondly, the heads of the black rust are attached so firmly in the stalk or cup that it is quite impossible for the wind or any other agent, as observations and facts necessarily require, to break them off and disseminate them for germination. I have kept for more than a year, many of the parasitic plants of the black rust, collected at different stages of maturity, and have found it very difficult, even after all that time, to separate the heads from the cups. Thirdly, those plants would have only one seed each, and because of this, would become extinct in a very short time, since not all seeds produce a plant, many of them being sterile and a large number being unable to find a place

to root. Nor can that hypothesis explain why the rust spread so rapidly and to such an extent as to occupy so many provinces at one time as it did in Italy last year. A single seed per plant would not account for their great spread, and besides, one would have to assume that in the preceding year the rust had been as prevalent as in the following year, which is truly absurd.

It is much more probable that those bodies are the fruits or pericarps of the rust plants. We have a thousand plants that bear their pericarps on the tops of the stem or stalk, as in the various species of molds, which are analagous to these. I must confess that with all the care I have used, I have never been able to observe those balls inside the heads of the black rust plants similar to those first discovered by the well-oculated Micheli in the mold plants. Not only have I never been able to see any one of these which had opened by itself naturally, as can normally be seen in the higher plants nor have I ever been able to see any of the red-rust eggs which had opened by themselves. But all these things do not, in truth, prove that the heads of the black rust plants are not the pericarps of our parasitic plants. However, I cannot assume much concerning the nature of the real seeds of this plant without fear of erring. It is evident that they are never seen with certainty, but, in the final analysis, their imperceptible minuteness could render them invisible, even with the aid of the most delicate and accurate lens.

But it has been demonstrated that all plants are propagated either by seeds or by organic vegetable matter! And how absurd it would sound to say that they were propagated by some other means. Our microscopic grain rust plants are of the simplest, i. e., lacking totally canals and organs and one could almost think them formed of a pure inorganic gelatinous juice; and perhaps, because of their simplicity, they are the polipi of the vegetable kingdom. Dillenio, the great botanist and observer, who, more than any other, has examined the microscopic imperfect plants, does not believe it absurd to maintain that such plants, which form the connecting link between the vegetable and the mineral kingdoms, may

have the same origin as stones and minerals, which certainly do not have real seeds.

Although positive observations are lacking to justify the conclusion that real seeds are present in the plants of the black rust, we have many observations that lead us to believe that the eggs of the red rust are the fruits, pericarps or receptacles of real seeds. I have succeeded at various times in opening some of these minute eggs with a sharp needle and have found them filled with small, ovoid and slightly transparent bodies. This is even better observed when the small bodies are lightly crushed between two thin glass slides. In order to observe them properly it is necessary also to add a small drop of water between the two slides and to apply only a slight pressure, since too much pressure will crush all the material and only an uniformly homogeneous, gelatinous mass will be seen. When my technique was successful, I have been able to count as many as 20 of those ovoid granules, that had issued from the eggs, floating freely about in the water. The egg appears crushed but its membrane is not very fine nor very transparent. This observation is very difficult and is rarely successful even when the greatest possible precautions have been taken. We see, then, there is some foundation for the belief that the eggs of the red rust plants are real pericarps containing seeds, the latter being the above-mentioned oviform granules, which can be seen inside the egg. These observations lead us to hope that we shall some day also establish some more certain facts about the seeds of the black rust plants.

However that may be, it is certain that the black rust, as well as the red rust, of grain consists of real plants, even though they must probably be placed in the imperfect group, so called by botanists because of the lack of many parts found in the more common plants. But lack of knowledge concerning those parts cannot hide or destroy certain facts. M. Guettard, in an excellent memoir included in the Proceedings of the Paris Academy of Science, 1756, separates parasitic plants into two groups, the true and the false. He called false plants those that attach themselves to others, forming ulcers in which

they live without causing damage and offense to the principal plant; for example fungi, lichens, and many other plants that climb or grow on the (host) plants. The true parasite is the one that attaches itself to healthy and undamaged plants, which forms lesions and wounds on them by introducing their roots or absorbing papillae into them and living at their expense; for example *Cuscuta, Clandestina, Ipocistide, Orobanche,* and the Orobancoid-like mistletoe. It appears that our rust plants should be placed between these two types of parasites, since it seems certain, on the one hand, that they attach themselves to the grain plant only when there is a rupturing of the vessels and a diffusing of the humors, and that, on the other hand, they feed or nourish themselves at the expense of the stalk or leaves of the grain plant; thus they would be called semi-parasites.

Since we have concluded and established the fact that the grain rust is a mass of small parasitic plants, found in incalculable numbers, it is easy to understand the effects produced on the growing, immature grain. First of all, if the stalk and the leaves are attacked by this terrible malady, the best set (of kernels), promising a heavy yield, is reduced to nothing or almost nothing because such a great number of greedy and gluttonous plants absorb nearly all the nutritive humor of the grain, causing it to become wasted and consumed because of the loss of the nourishing chyle.

Provided that the weather favors vegetative growth, the disease will not usually be serious if the rust attacks the young grain before it has set its stalk. In this case the parasitic plants suck the humor from the leaves only; the grain can set new sprouts, recover, and well nourish its kernels when the stems are not damaged or vitiated.

If, on a vigorous and extensive rust outbreak, there falls suddenly a heavy rain, which wets and washes thoroughly the infected stalk and grain leaves, the rust will almost totally disappear, and the grain will suffer very little damage. The reason for this is very clear. The sudden rain, pouring upon it on all sides, causes them (the eggs) to break from their

stalks and scatters them before they are hardly able to take root, or before they had enough time to suck very much nutriment juice from the grain.

The kernels will be empty and will consist only of pericarps when harvested, if they are attacked by the rust when still tender and milky. The kernels will be only slightly thinner and lighter if the rust attacks the plant when it is nearly mature and the kernels have acquired some consistency and already have a dense, hardened humor. In the first case, where the parasitic plant absorbs the nutrient humor of the grain, the spike remains improverished for which reason it cannot nourish itself and grow or develop the proper starch content. In the second case the grain is already formed with a hard pulp and the loss of the humor taken from it makes it lighter but cannot make it void of substance.

It is now clearly understood how the rust can cause so much damage in such a short while at the time of maturity. We are dealing with a great number of hungry and insatiable plants that live by violence, feeding at the expense of the tender green plant; they grow rapidly, thanks to the food that they steal from the grain, feeding in a great number of places, stopping entirely the flow of the already prepared and digested juice, which is to nourish the grain and to be converted into pulp and flour. By observation, it is a fact known to all observers that the parasitic plants are able to cause comparatively much larger plants to become ill by sucking from them quantities of humor much larger, in comparison, than the parasitic plants themselves.

Modern observers have noticed that the rust of grain is most prevalent when heavy dry fogs are followed by a hot sun and cold nights. The nutrient juice, held during the night in the very thin canals near the epidermis of the plant, is heated by the hot sun in the daytime, causing it to become turbid, altered, and fermented, which, in turn, causes the very delicate vessels to break and the altered humor to exude. The rust spots of the disease are always found on the longitudinal axis of the grain plant and never on the transverse axis, since the fibers and the vessels are broken by the lesser re-

sistance and open more easily on the longitudinal axis. The seeds or buds of the parasitic plant, with which the air is always filled to abundance, as it is with seeds or buds of a thousand other microscopic plants, such as molds, lichens, fungi, etc., fall into these wounds or apertures, attach themselves and take root in grooves, where they come in contact with the exuded humor that is detrimental (to the grain) but at the same time suitable to fertilize and nourish the rust plants that develop with incredible rapidity in this medium.

I must not overlook mentioning an accidental observation I made which may prove very useful and may greatly diminish the amount of spoilage and ruin by the rust in times of famine. From a farm near the city I collected several grain plants that were still fresh and had become infected by the rust only a short time previously; I was careful in selecting only those that were seriously attacked and whose leaves and stalks were almost completely covered with a thick coat of the rust. The kernels of the spikes were greenish and tender and gave forth a milky humor when broken. All the parts of the plant dried up very quickly, since the season was very warm. I found the kernels hardened and resistant even to heavy pounding. They were somewhat lighter, thinner, and a little more wrinkled than healthy, mature kernels, but they contained white pulp of optimum quality, which could be used for bread. Such an observation caused me to wonder just how much grain had afterward been harvested from that farm; to my surprise, I learned that they had not harvested a tenth of the original amount of seed sown. I wrote to various people regarding this and found that many farmers in Tuscany, Bologna, and Romagna, who cut their grain at the first signs of rust, even while it was still green, had obtained yields that, although mediocre, were incomparably higher than the yields of neighbors who, under similar circumstances, had waited and had cut their grain at the regular harvest time. This important observation, which is as yet known to very few, should be followed up by an intelligent observer to determine the value of such a practice. The problem to be solved may be briefly stated as follows: "To establish and demonstrate whether it is practical to cut the grain while it

is still immature when you have a given quantity of rust infecting a province and a given degree of maturity of the grain." Surely, any one skilled in agriculture can readily see the value of such an investigation and can see the great difficulty of fixing precisely all the circumstances, so that such research may be useful and positive. It does not suffice to say, in general, that such a practice may be useful; we must determine when and to what extent it may be of value. In order to accomplish this the eye and head of a sagacious observer are necessary.

The reason for this unexpected observation may be easily explained; it is perhaps inherent in the very nature of the rust. The sun quickly hardens and fixes the milky juice of the kernel in the cut plant, which is unable to take up new humors, causing the water of succulent parts to evaporate and the cortex to harden and dry up, which, in turn, prevents the major part (of the humor) from leaving the kernels; in this way the kernels remain full and pulpy, though somewhat lighter. In the still green and uncut rusted plant, which is not prevented from absorbing the watery vapors during the night, the milky humor remains more dilute and watery. Since this humor is unable to mix with the other more dense and viscous juices, the real blood of the plants, it is stopped and absorbed in every part of the plant by the innumerable small plants composing the rust. The sun then compels the excessively fluid humor to leave the plant by transpiration, which causes the kernels to become impoverished and empty. The milky humor of the kernels may descend through the canals of the stalk, in that circulation which is admitted by all physicists to exist in plants, and, encounters everywhere the parasitic plants, which attract and suck it up, since, even in the case of the animal body, the humor flows most freely where it finds the vessels broken and meets with less resistance; thus it is also possible that the thin and fluid humor of the kernels still may be carried in large quantities to the wounds made in the stem where it affords nourishment to the enemy plants. However it may be, it appears that the facts are certain, and the problem, indeed, merits the attention of one who is interested in the welfare of society.

A long and well-understood series of observations on the rust of grain, made by an intelligent observer, might bring out more important lights not only on the nature of the disease but, also, on the nature and economy of the parasitic plants that produce it. Above all, it is necessary to observe the beginning of the disease, to examine closely the condition of the plant, the germination and development of the parasitic plant, and, finally, the real nature, the origin and causes of the rust. It will then be less difficult to find remedies that will enable us to exclude from our wheat fields such a terrible scourge, which impoverishes and starves us.

"If we had," says Duhamel, "sufficiently accurate knowledge of the causes of the rust, we should probably succeed in finding more easily protective agents against this disease; but, meanwhile, it is very profitable to assemble all the observations made on this disease by the lovers of Agriculture."

The talents of many learned botanists could be used to greater advantage in the little-known fields of the vegetable kingdom, if, instead of furiously pursuing new systems and enriching with new barbarous words one of the most delightful and perhaps the most useful branches of the science of nature, they observed the structure of plants more closely by examining their nature and economy more in detail, especially in the case of the so-called imperfect plants, which can be properly observed only with the microscope, and concerning which confusion, uncertainty, and obscurity reign even after Micheli and Dillenio. It is true that there have been very few botanists who have occupied themselves with the more exacting and tedious details of these minute plants; and among these we must recognize Micheli who found the male organs and the seeds of the fungi, Dillenio who first observed the seeds of the mosses, and, finally, Bernard Jussieu who gave to the science of Botany the stamens and the seeds of ferns, the exploding of dust in fertilization, and the true origin of the corals, the madrepore, the lithophytes, serophytes, and many other marine plants. But these men were very great and exact observers, and only observations guided by the spirit of analysis can enrich us with important new truths. The physicists could also turn their researches towards plants,

and from their united labors we might hope for almost anything. The vegetable kingdom presents a vast field in which observers can usefully occupy themselves; the structure and economy of the plants are the only physical science of those organized vegetable bodies; a vast and difficult study, worthy of occupying the mind of any philosopher, both for the great value that it can bring to society and for the inward pleasure, little understood by the multitude, that is gained when one penetrates into the hidden secrets of the delicate mechanism animating and governing those regular and highly complex bodies. But what does not the vegetable kingdom owe to a Hales, a Bonnet, or a Duhamel in these latter times? The difficult discovery of the male organs and the seeds of the *Fucaceae* must be credited in the final analysis to the very eminent French physicist, Réaumur.

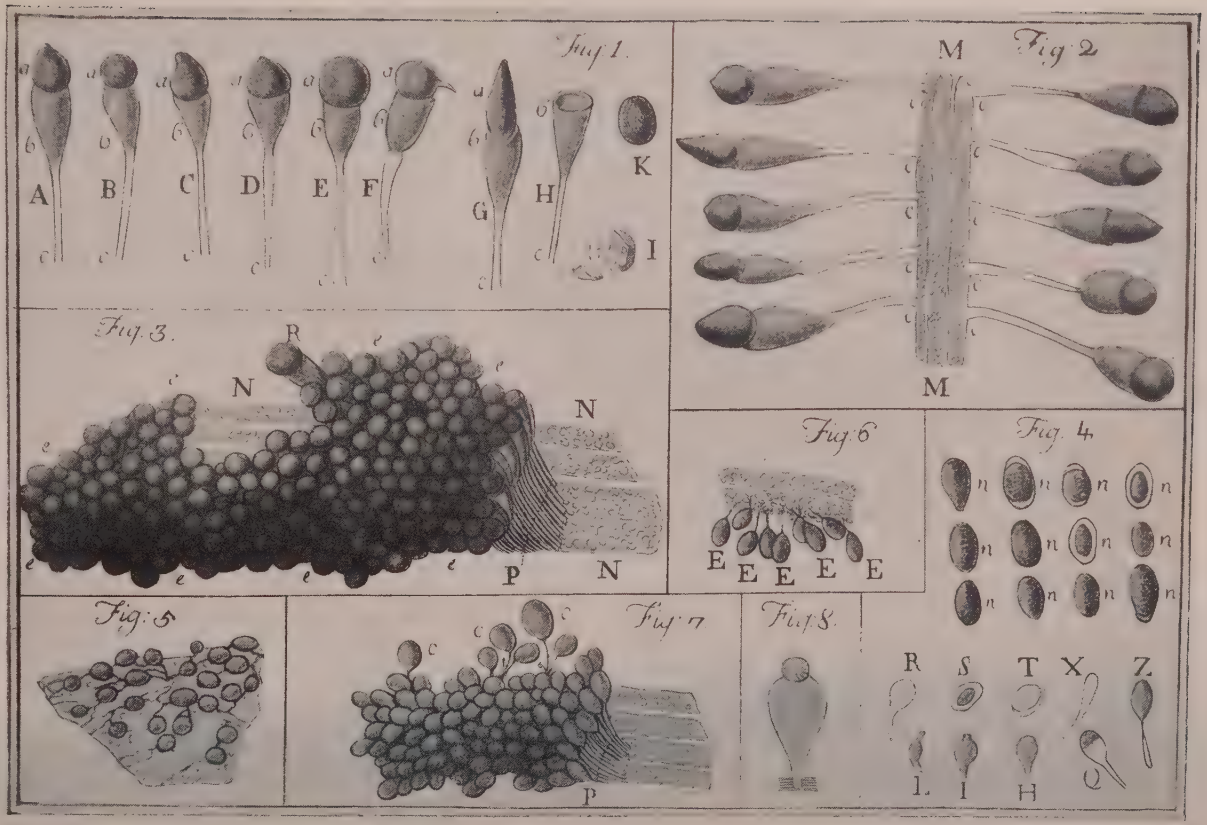
Fig. 1.
A
B
C
D
E
F
G
H
K
I
Fig. 2
M
M
Fig. 3.
R
N
N
P
N
Fig. 6
E E E E E
Fig. 4
Fig. 5
Fig. 7
P
Fig. 8.
R
S
T
X
Z
L
I
H
Q

EXPLANATION OF THE FIGURES[6]

Figure 1

A, B, C, D, E, F, G, represent seven parasitic plants of the black rust observed on a glass slide with a very strong lens.

a. a. a. a. a. a. a. The heads or caps of those seven plants, the heads are of different shapes and sizes; some are spherical as may be seen in plants B and E; others are olive-shaped as in G; and others still different as in A and D.

The very round head in F carries a curved cone, which is very rarely observed.

b. b. b. b. b. b. b. The bodies or cups of the plants of various sizes and shapes, with circular edges, more or less raised, at the tips of which the heads are planted and in which they are set, although always in different positions and manners.

c. c. c. c. c. c. c. Transparent stems of variable diameter, which end in and are tied to the cup.

H. A cup with the stem or appendage, but without the head, and the top hollowed, making a little depression.

K. A very large egg, exactly similar to those found in the reddish yellow rust, observed on the glass only once in the immediate vicinity of H.

I. An egg that was crushed between two slides and observed with a very strong lens; many extremely small bodies are seen coming out, the same oviform bodies appear to be discernible in the head of plant, E.

Figure 2

M. M. A small section of the stalk of a grain plant observed on a glass slide.

c. c. c. c. c. c. c. c. c. c. The appendages or stems of ten plants inserted in the above-mentioned stalk as appears in the same figure.

Figure 3

N. N. N. A piece of grain stalk.

e. e. e. e. e. e. e. e. A rust spot observed with a powerful lens. In those spots all the heads of the small plants may be seen touching each other and their stems are disposed perpendicularly on the stalk.

P. A mass of appendages or stems of those parasitic plants rooted in the stalk and leaning on one another.

R. One of those plants separated and slightly raised above the others.

Figure 4

n. n. n. n. n. n. n. n. n. n. n. n. The eggs of the red rust observed with a very powerful lens and represented with their least ordinary

[6] Figures 1 to 8, as published in the original text, were done in natural color.

differences. They are generally all pointed and some appear surrounded by a transparent roll (or cake); others are seen with a ring resembling the ring of Saturn.

Q, R, S, T, X, Z. Very rare bodies of the reddish yellow rust, although some of those that have stems are found in the black rust.

Q. A body with a stem ending in a point. The stem and half of the head are transparent; and the other half is reddish yellow.

R. Another body with stem, entirely transparent, with a few dark spots in the acuminate head.

S. An egg with a wide roll around it; in its center another opaque egg, reddish brown.

T. An irregularly round, totally transparent body.

X. A very long thin body with a stem, entirely transparent.

L, I, H. Three eggs of the reddish yellow rust, crushed between two glass slides.

L. An egg with two large handles, slightly curved, which project from the two extremities.

I. Another egg with straight handles.

H. A third egg with only one handle.

FIGURE 5

A piece of the stalk of a grain plant with many filaments laden with eggs of the red rust.

FIGURE 6

E. E. E. E. E. Some plants of the red rust attached by their stems on a fibril of a grain leaf.

FIGURE 7

A red rust spot.

P. The stems of these plants, which stand perpendicularly on a piece of the stalk of a grain plant.

c. c. c. Separate plants with filaments or stems, to which the eggs of the red rust are attached.

FIGURE 8

A microscopic plant observed by Backer in the moist sand of the Thames.